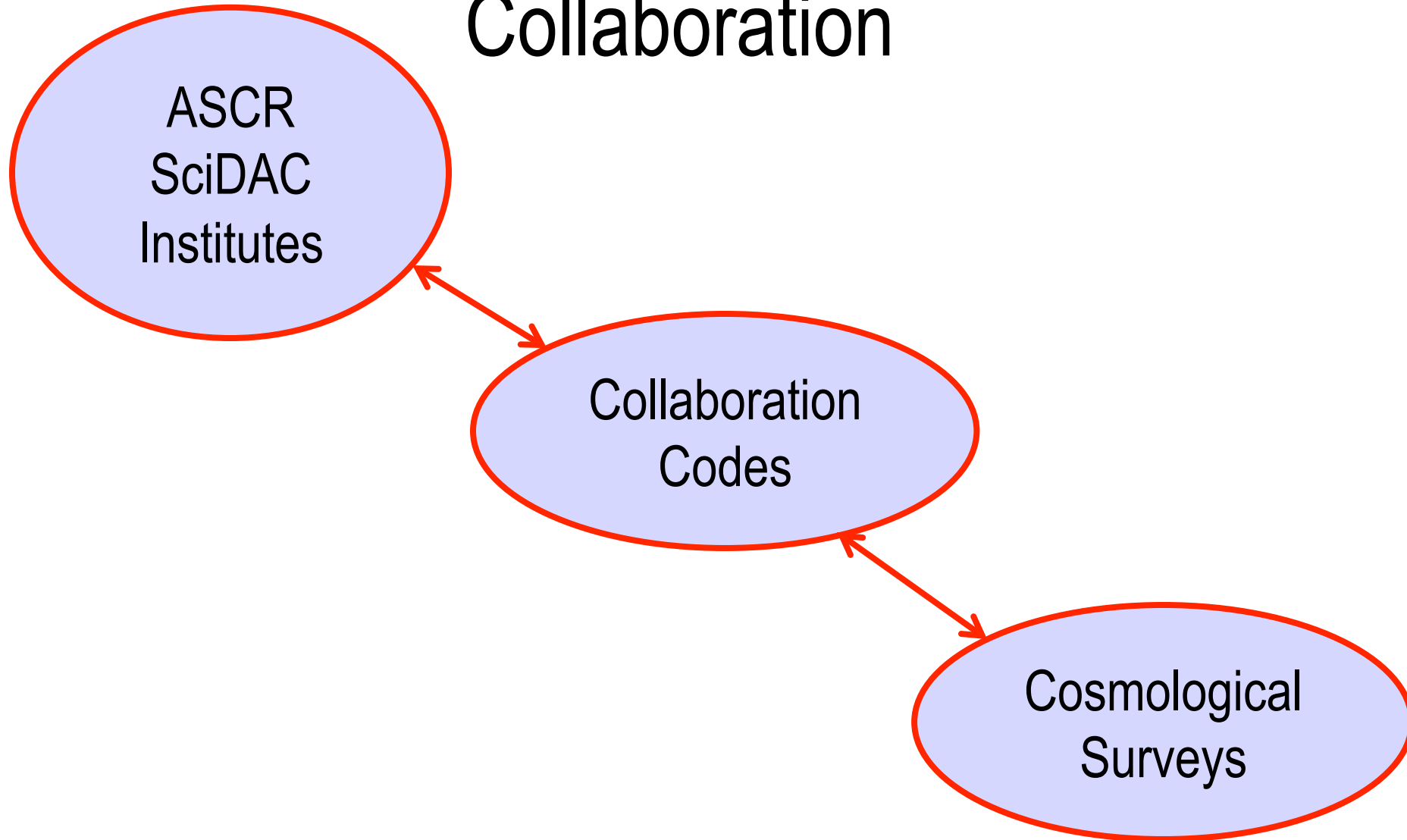
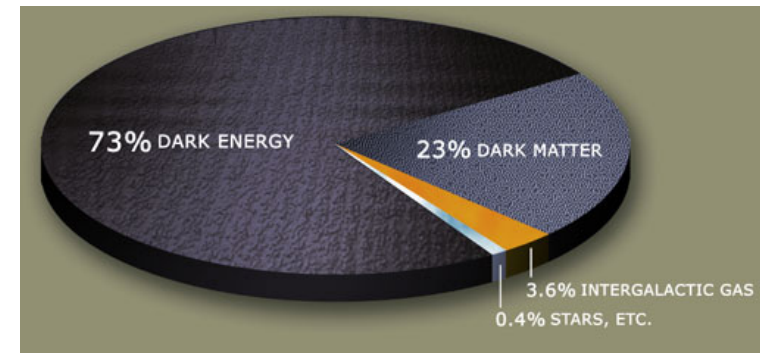


# Cosmic Frontier Computing Collaboration



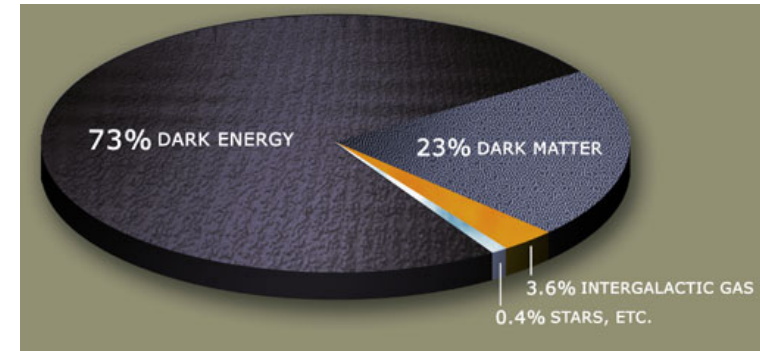
# Dark Energy

- Mysterious substance contributing most of the energy in the Universe



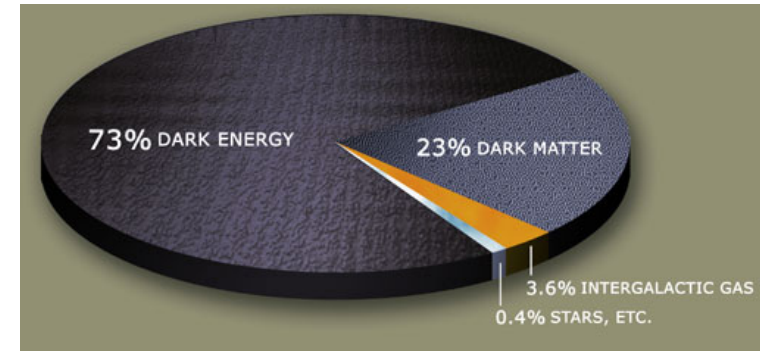
# Dark Energy

- Mysterious substance contributing most of the energy in the Universe
- Energy density remains constant as Universe expands!



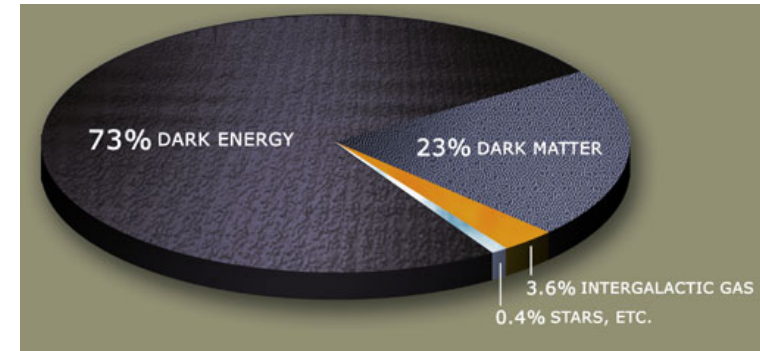
# Dark Energy

- Mysterious substance contributing most of the energy in the Universe
- Energy density remains constant as Universe expands!
- Energy associated with empty space? [Recall Heisenberg]



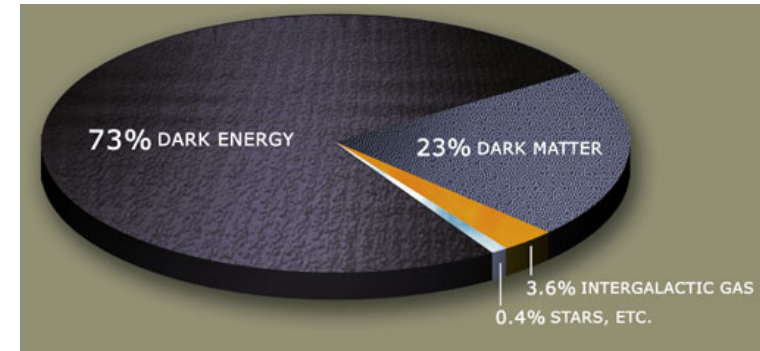
# Dark Energy

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- Answer wrong by 120 orders of magnitude

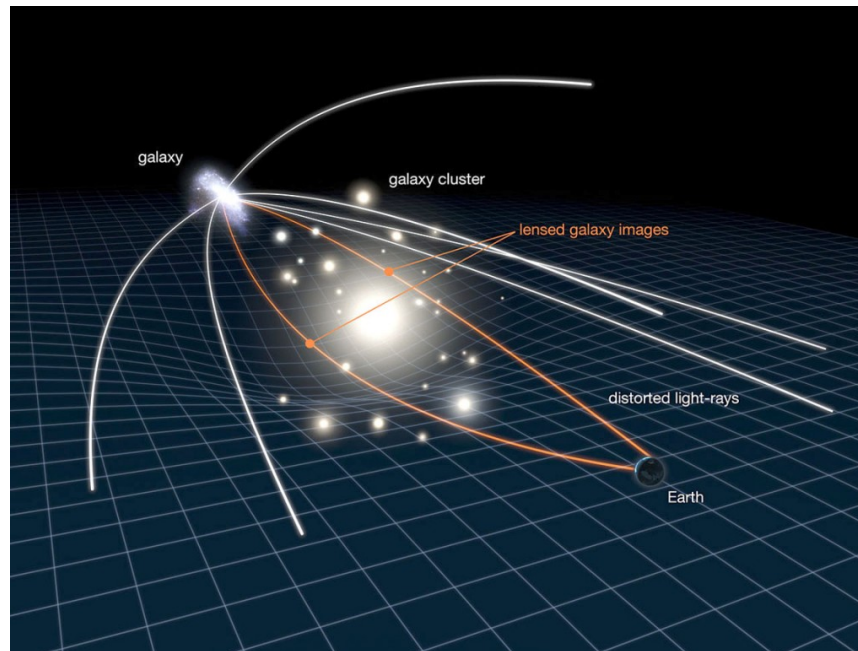


# Dark Energy

- Mysterious substance contributing most of the energy in the Universe
- Energy density remains constant as Universe expands!
- Energy associated with empty space? [Recall Heisenberg]
- Answer wrong by 120 orders of magnitude
- Need to study observationally



# Gravitational Lensing



- Light paths distorted by intervening structure
- Distortions depend on both distance-redshift relation and growth of structure
- Both of these things are affected by the nature of dark energy

# Galaxy Ellipticities

Spherical  
galaxy



Mass



# Galaxy Ellipticities

Spherical  
galaxy



Mass

# Galaxy Ellipticities

Spherical  
galaxy



Mass

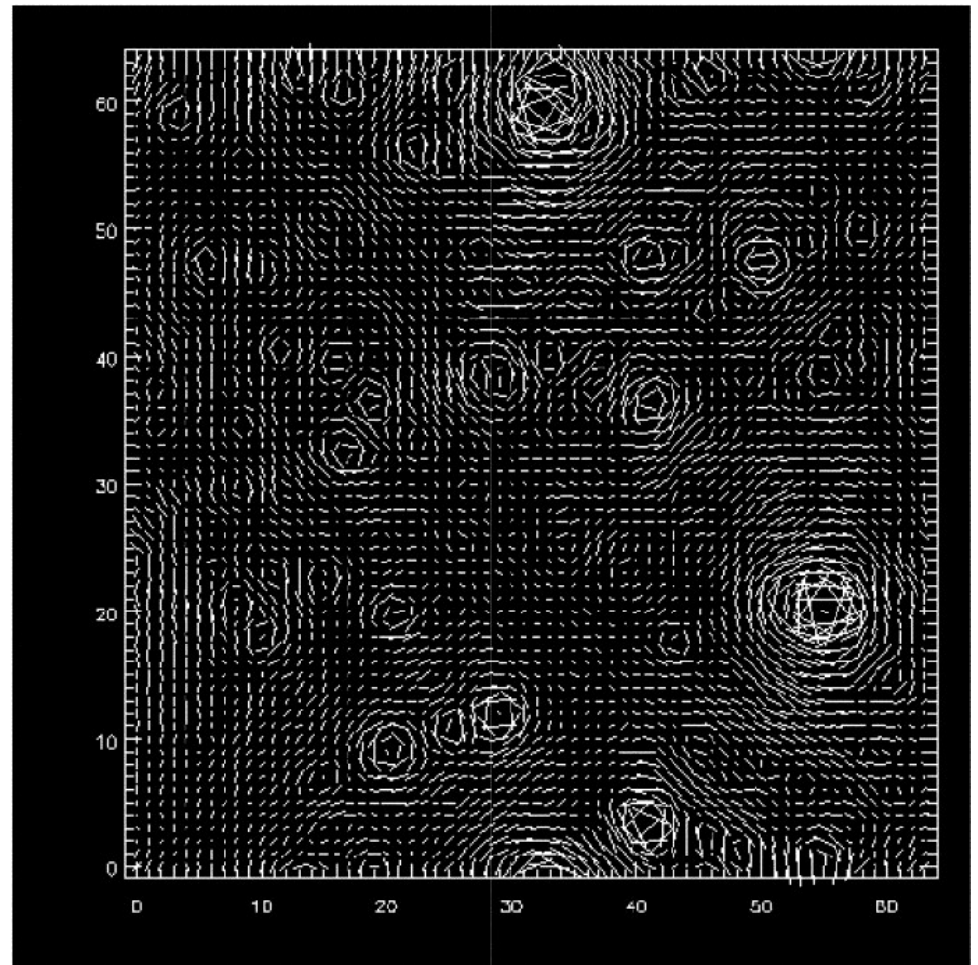


Galaxy appears  
elliptical



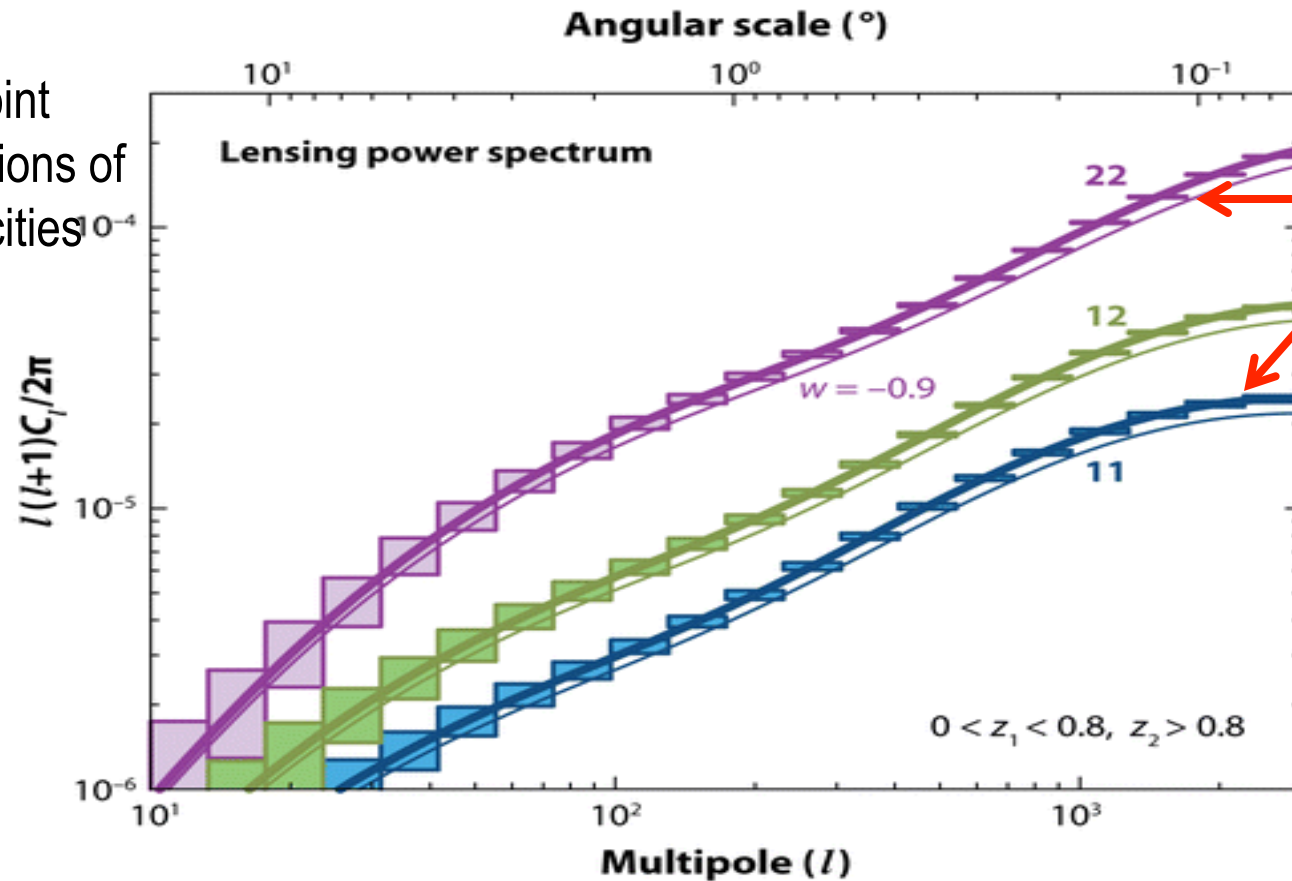
# Extracting information from galaxy ellipticities

- Mean ellipticity is zero
- Information is contained in variance and correlations



# Quantification: Spectra

2-point  
Correlations of  
ellipticities



Galaxies in  
different redshift  
bins

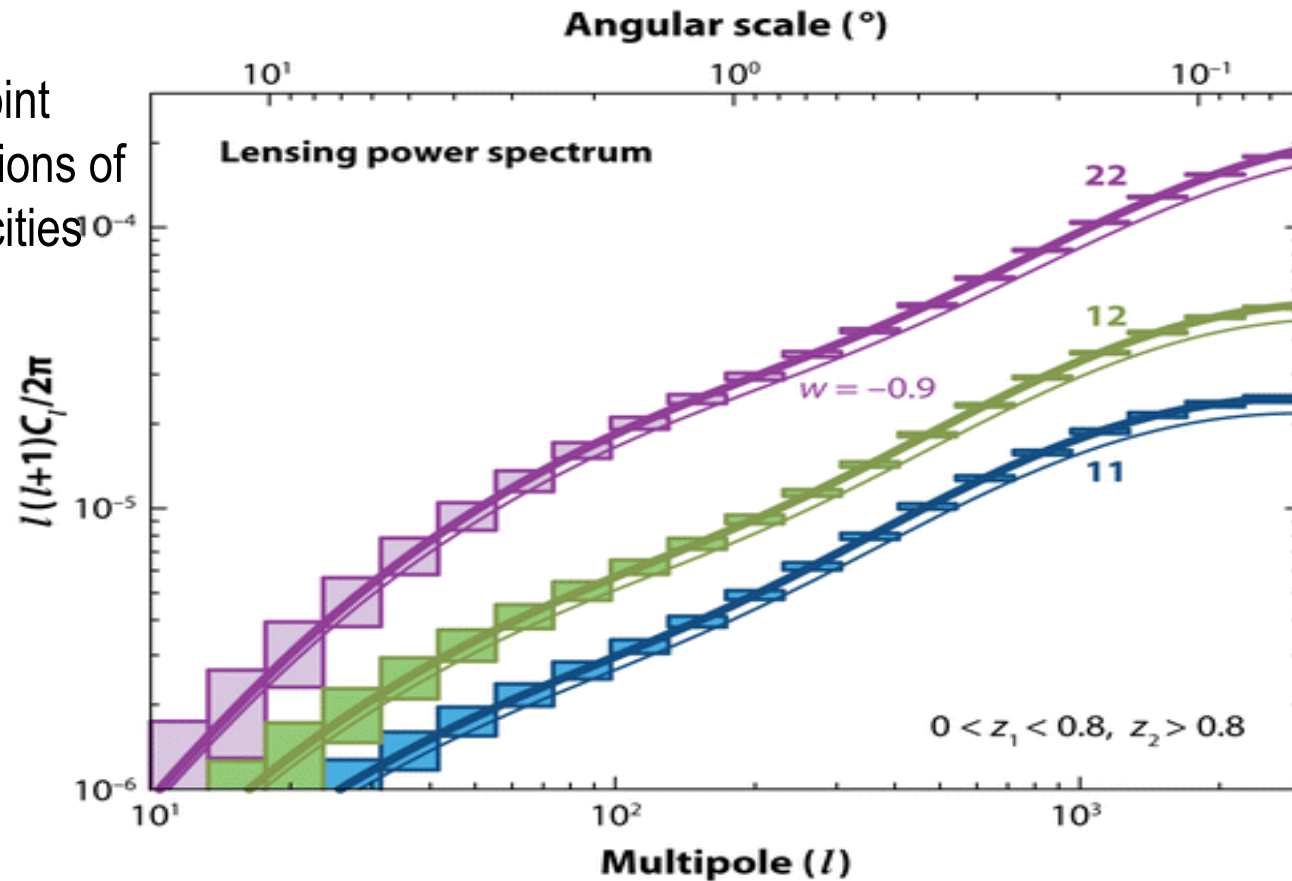


Hoekstra H, Jain B. 2008.

Annu. Rev. Nucl. Part. Sci. 58:99–123

# These spectra computed neglecting baryons (“N-Body”)

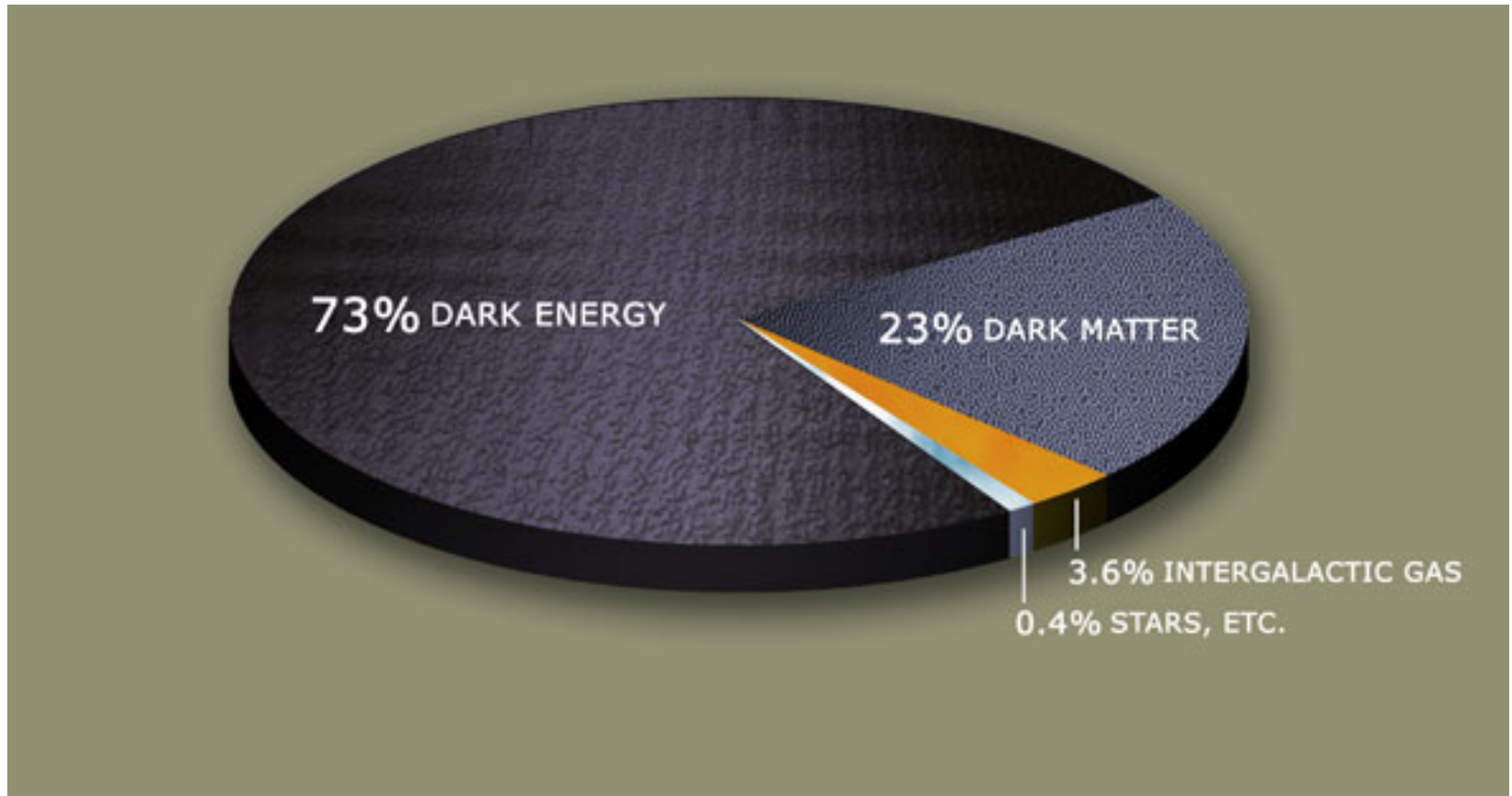
2-point  
Correlations of  
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Hoekstra H, Jain B. 2008.

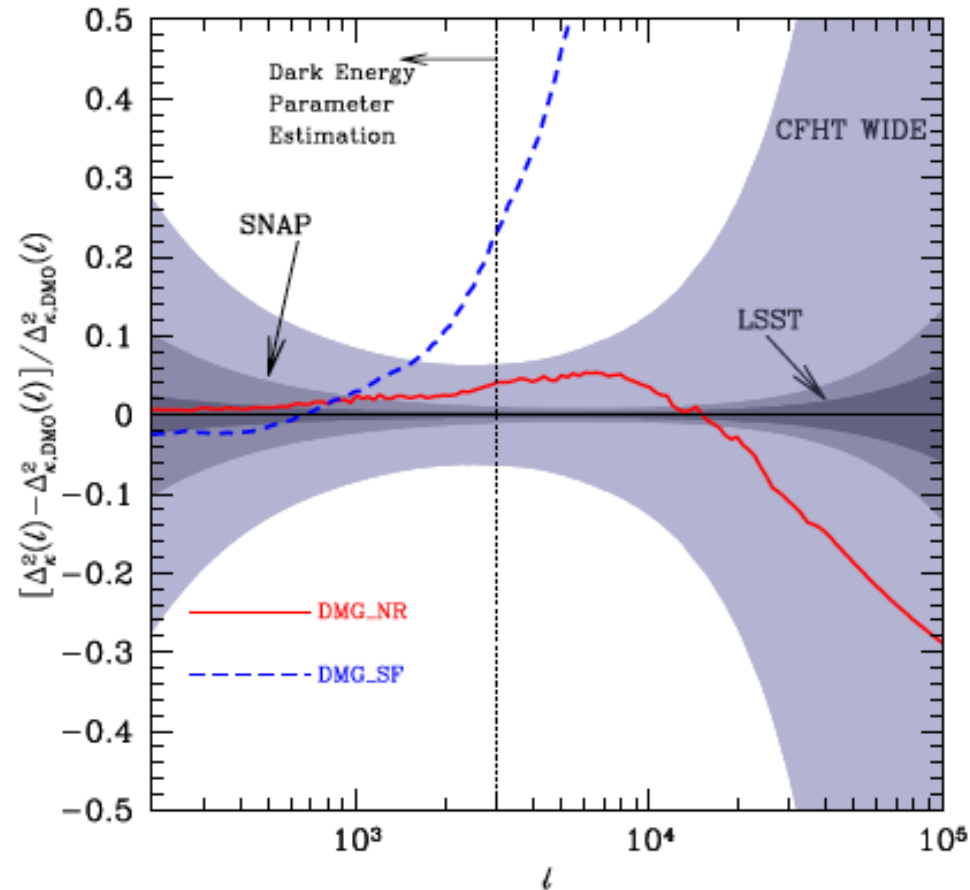
Annu. Rev. Nucl. Part. Sci. 58:99–123

# Need to account for baryons ("Hydro")



# Baryonic Effects

- **Differences large:** red & blue curves outside projects errors from upcoming surveys
- **Effect uncertain:** different implementations give vastly different results



Rudd et al. 2007

# Dark Energy Survey

Identified as one  
of key  
systematics by  
DES Weak  
Lensing Working  
Group





# Study with latest Simulations

(Zentner, Semboloni, Dodelson, Eifler, Kraus, Hearin)

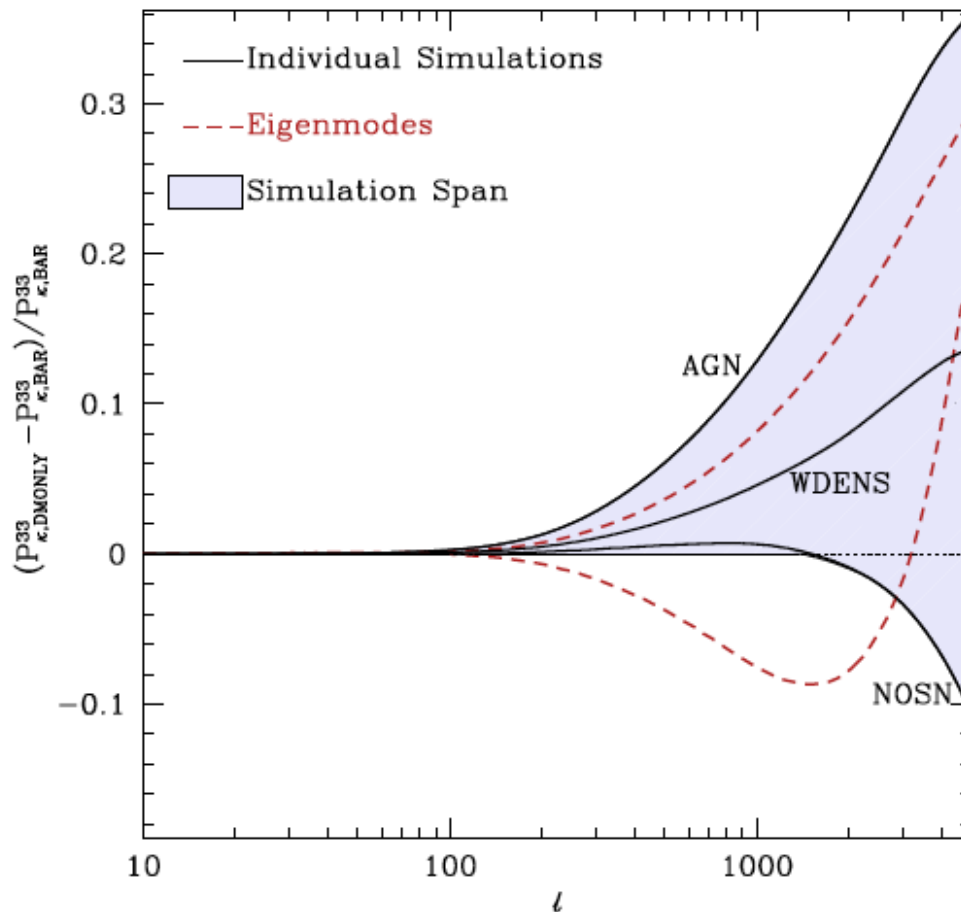
	Box Size (Mpc)	N	Mass resol	Spatial resol
Jing et al 2006	100	512	7e8	?
Rudd, Zentner, Kravtsov 2008	60	256	1e9	2 kpc
Guilett, Teyssier, Colombi 2010	50	1024	1e7	1 kpc
van Daalen et al 2011 (OWLS)	100	512	7e8	2 kpc

# Overwhelmingly Large Simulations (OWLS)

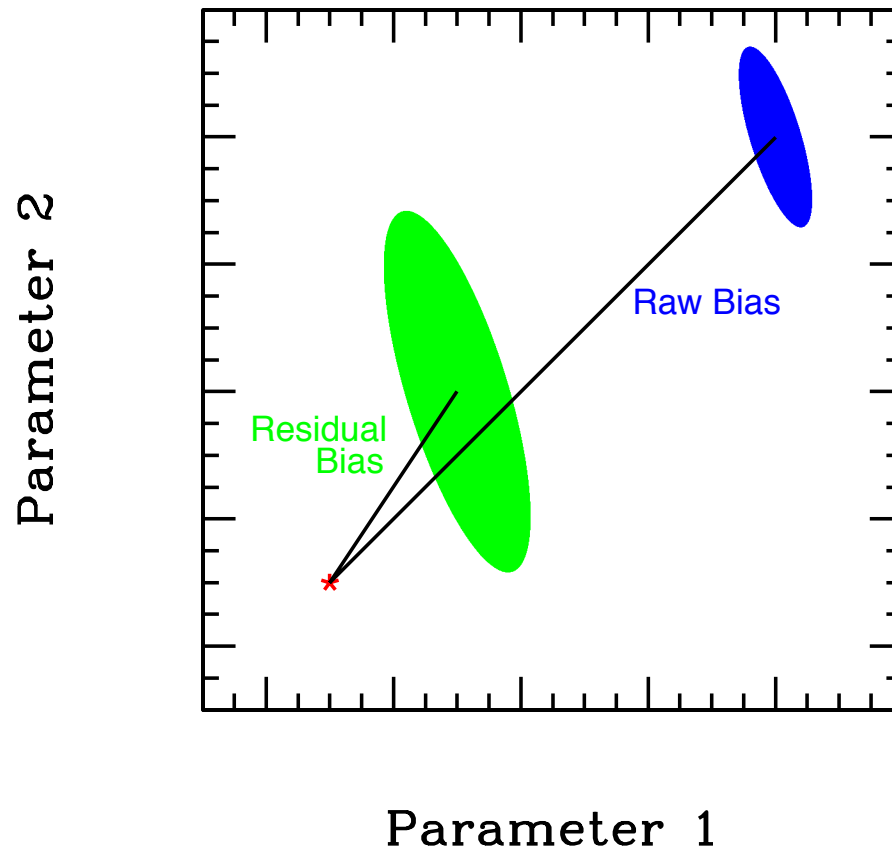
~10 simulations with same initial conditions/resolution/box size, but different prescriptions for baryons

Simulation	Description
<i>AGN</i>	Includes AGN (in addition to SN feedback)
<i>AGN_WMAP7</i>	Same as <i>AGN</i> , but with a WMAP7 cosmology
<i>DBLIMFV1618</i>	Top-heavy IMF at high pressure, extra SN energy in wind velocity
<i>DMONLY</i>	No baryons, cold dark matter only
<i>DMONLY_WMAP7</i>	Same as <i>DMONLY</i> , but with a WMAP7 cosmology
<i>MILL</i>	Millennium simulation cosmology (i.e. WMAP1), $\eta = 4$ (twice the SN energy of <i>REF</i> )
<i>NOSN</i>	No SN energy feedback
<i>NOSN_NOZCOOL</i>	No SN energy feedback and cooling assumes primordial abundances
<i>NOZCOOL</i>	Cooling assumes primordial abundances
<i>WDENS</i>	Wind mass loading and velocity depend on gas density (SN energy as <i>REF</i> )
<i>WML1V848</i>	Wind mass loading $\eta = 1$ , velocity $v_w = 848 \text{ km s}^{-1}$ (SN energy as <i>REF</i> )
<i>WML4</i>	Wind mass loading $\eta = 4$ (twice the SN energy of <i>REF</i> )

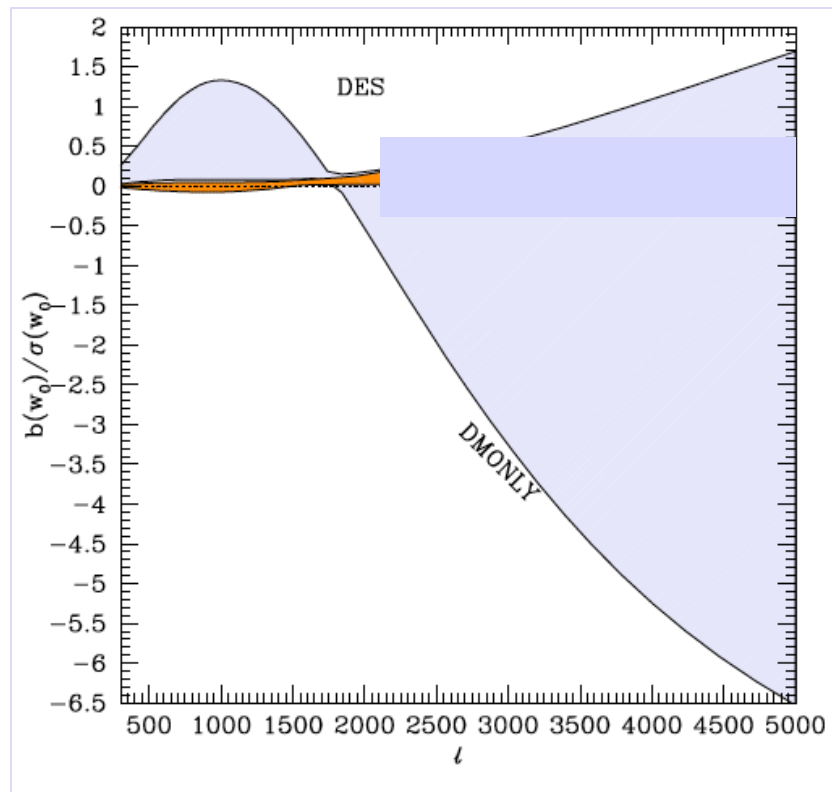
# Baryonic Effects at least as large as in Rudd et al.



# How bad is ignoring the effect? (Raw Bias)



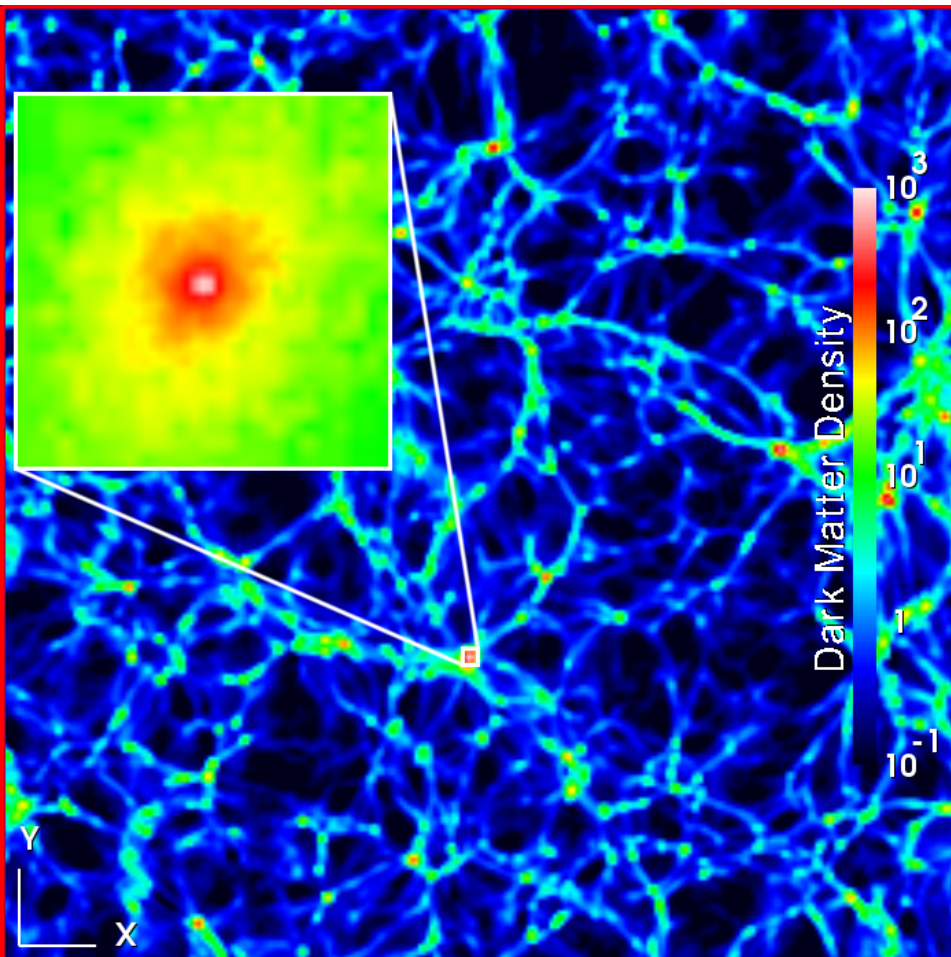
# Raw Bias is significantly larger than statistical error for many of the simulations



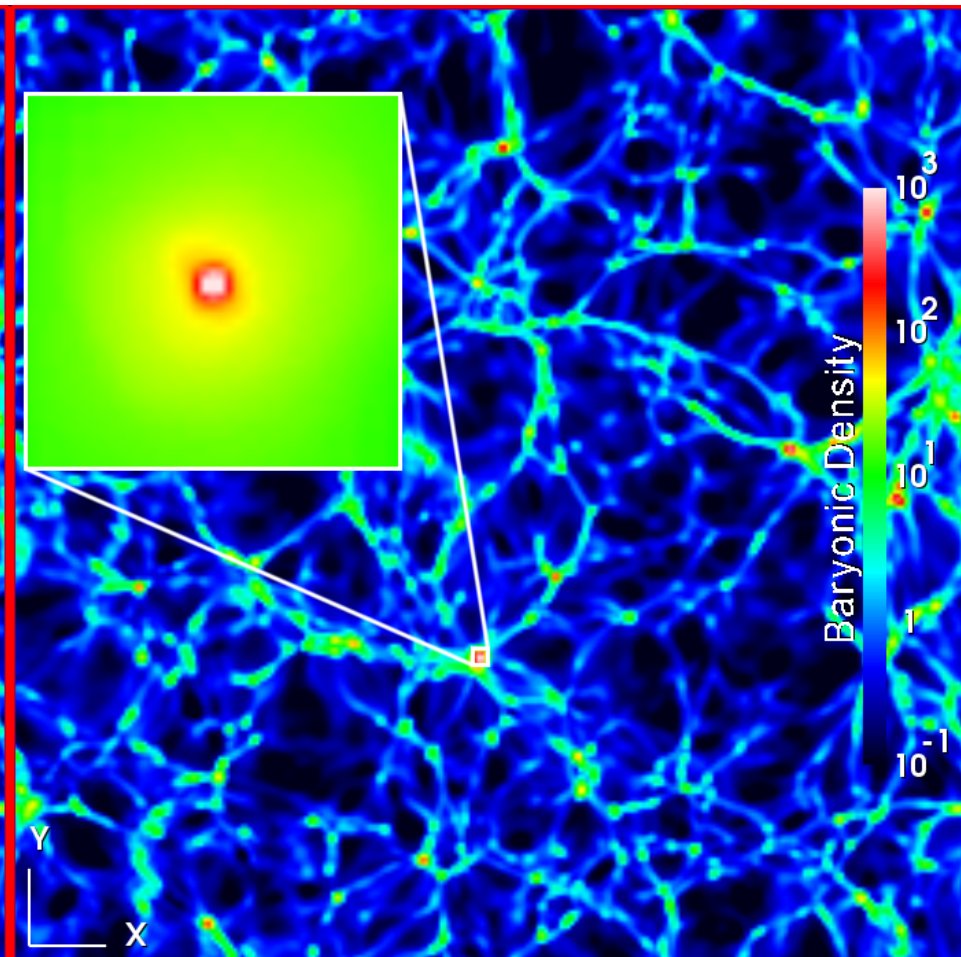
How can we mitigate this?

Recall from Nick's talk that baryons  
tend to make halos more concentrated

Dark Matter

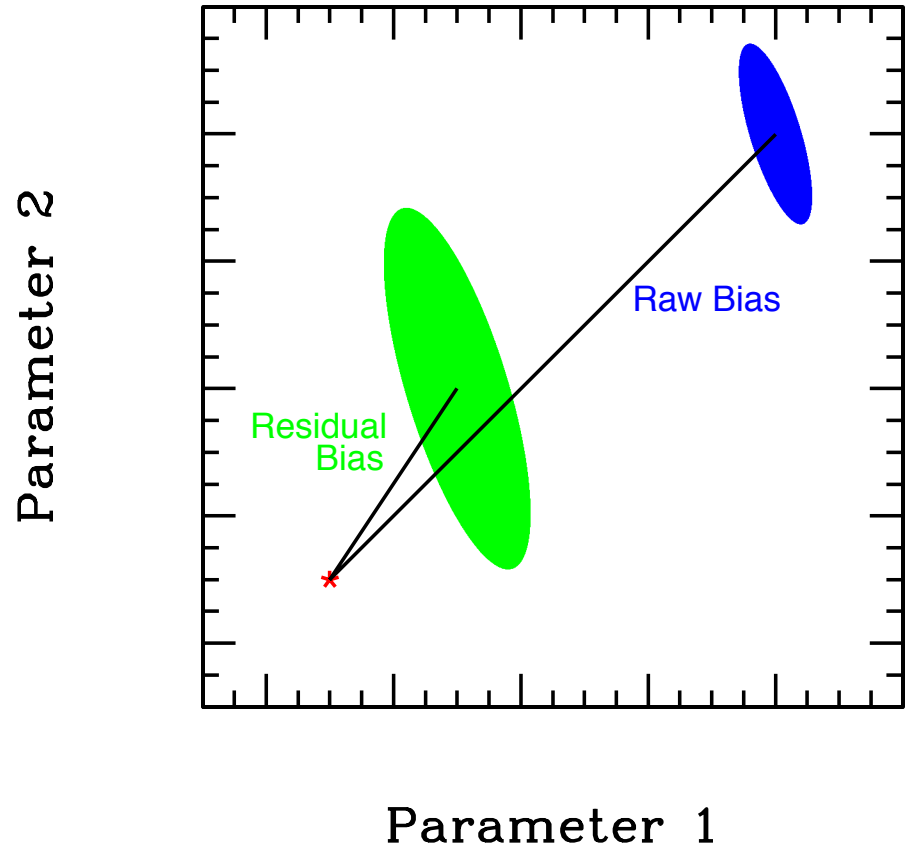


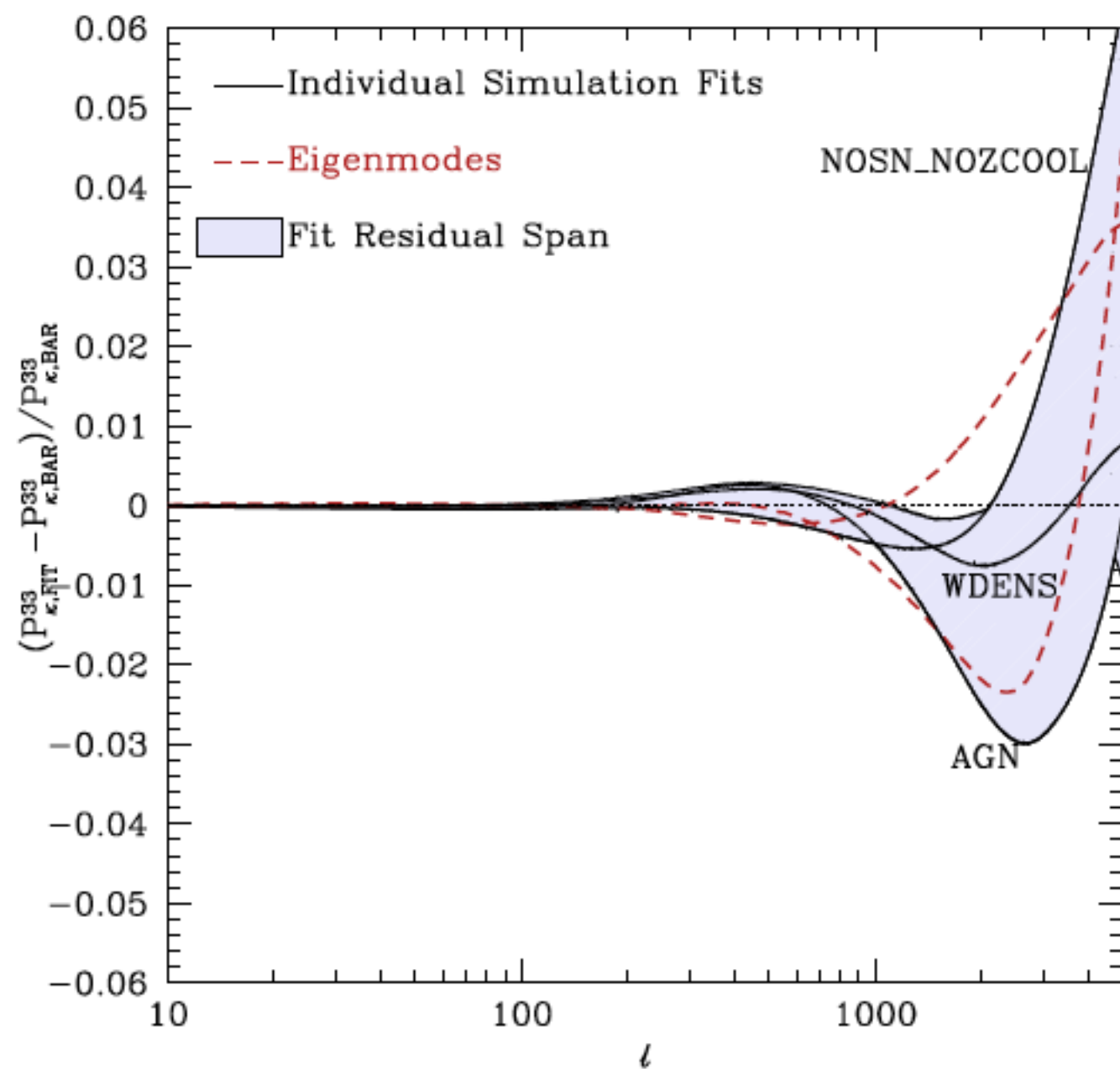
Baryons



# Mitigation Strategy

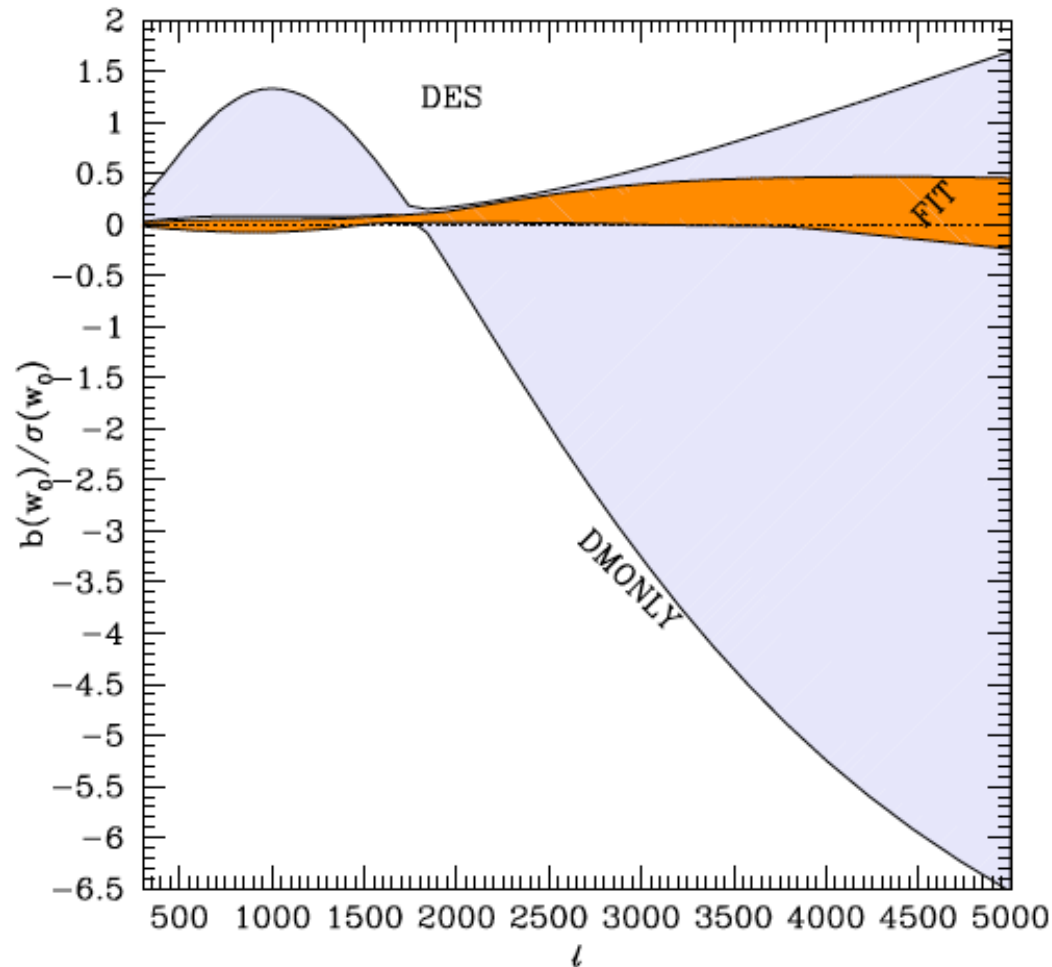
- Introduce new parameters (beyond the standard cosmological parameters) that model the new mass-concentration relation
- Fit for all parameters (cosmo + Mass-concentration)
- Errors will go up (green larger than blue) but residual bias should go down







Residual Bias smaller than Statistical error even if small angular scales are included



# Exciting Plans

	Box Size (Mpc)	N	Mass resol	Spatial resol
Jing et al 2006	100	512	7e8	?
Rudd, Zentner, Kravtsov 2008	60	256	1e9	2 kpc
Guilett, Teyssier, Colombi 2010	50	1024	1e7	1 kpc
van Daalen et al 2011 (OWLS)	100	512	7e8	2 kpc
Our plan	200	1024+	7e8	<1 kpc

We [Nick Gnedin, Scott Dodelson, John Freeman, Qiming Lu]  
look forward to working with you!